IAP Dynamical Climate Prediction System and its application to the climate anomalies predictions over China

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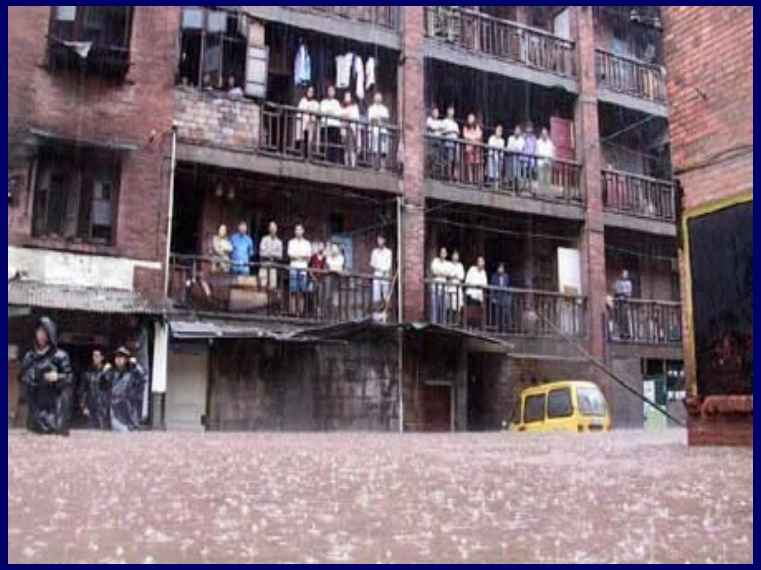


Climate Anomalies over China

China

- ￥10 billions economic loss annually
- ￥78 billions economic loss caused by 1991 severe flooding event over Huaihe and Yangtze River，more than 5000 dead
- ￥248 billions loss caused by 1998 severe flooding events over China, more than 3600 dead

Venezuela

Germany

Some floods in 2002

India

Source: Red Cross

Why Seasonal Prediction

- Growing demand for reliable seasonal forecasts

International Research Activities on the dynamical Seasonal prediction

- CLIVAR (Study of CLImate VARiability and Predictability)
- SMIP (Seasonal Prediction Model Intercomparison Project --- Phase I & Phase II)
- NSIPP (NASA Seasonal to Interannual Prediction Project)
- PROVOST (PRediction Of Climate Variation On Seasonal to interannual Time scale)
- DEMETER（Development of a European Multimodel Ensemble system for Seasonal to inTERannual prediction)

……

Dynamical Seasonal Prediction Activities in IAP/CAS

- **First Extraseasonal Prediction by Numerical Climate Models in 1988**

  Zeng et al., 1990

- **Establishment and improvement of IAP Dynamical Climate Prediction System (IAP DCP)**

  e.g., Li, 1992; Zeng et al, 1997; Lin et al, 1998; Zhou et al. 1998; Wang et al., 2000, …

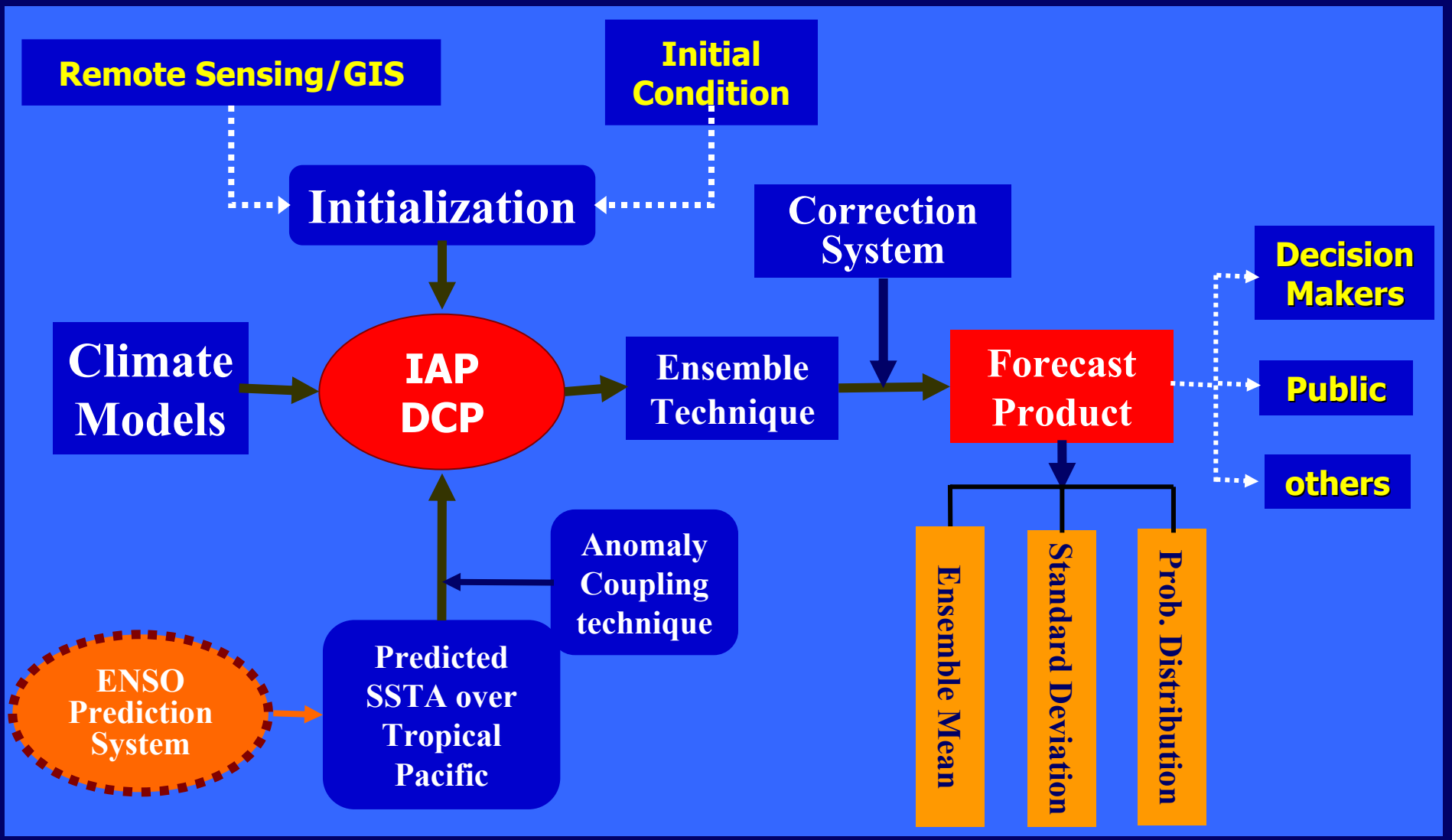
- **Numerical Seasonal Prediction of Climate Anomalies since 1990 by IAP DCP**

  Zeng et al., 1990; Yuan et al., 1996; Zeng et al., 1997; Lin et al., 1998, 1999, 2000; Zhou et al., 2001, …

Components of IAP DCP

- IAP ENSO Prediction System
  - IAP TOGA-I (AGCM, OGCM, CGCM, LSM ….)
- Prediction Integrations and Anomaly coupling Technique
- Ensemble Prediction Technique
- Correction System
- Prediction Products

IAP Dynamical Climate Prediction System (IAP DCP)



Characteristics of IAP GCMs

- The subtraction of a standard(reference)stratification both in the AGCM and OGCM for reduction of truncation errors
- The removing of the rigid-lid approximation in the OGCM
- The compactness and convenience in mathematical formulation and numerical computation

- ★ Gridded model
- ★ Long-term integration
- ★ AMIP, SMIP, PILPS Projects

IAP GCMs

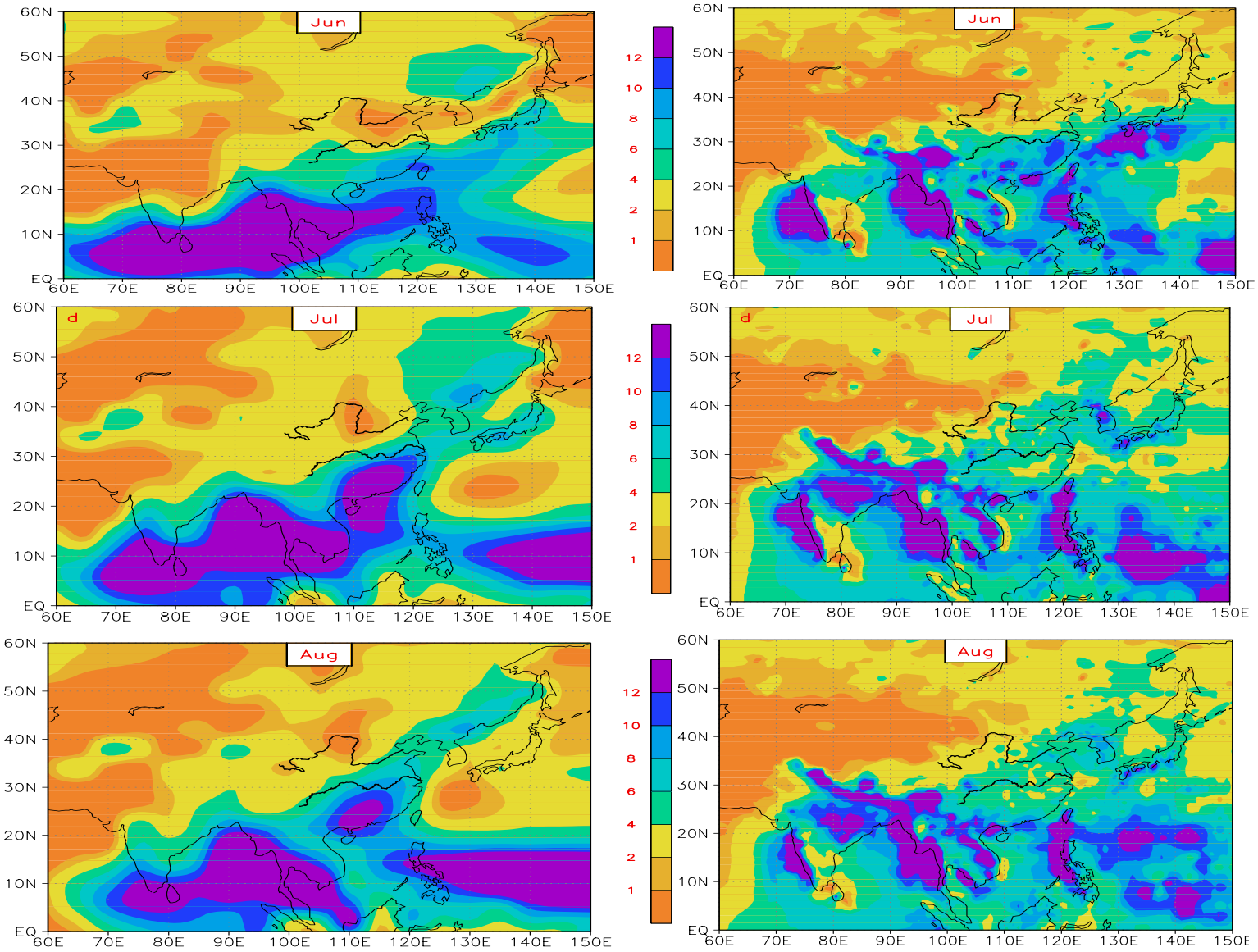
- **CGCM 1: IAP AGCM-I + 4L 4° x5° P-OGCM(1989)**
  - Seasonal Prediction Experiments
  - 4L Pacific OGCM used in **Oceanic Data Assimilation**
- IAP AGCM-I + 4L G-OGCM(1992)
  - ENSO simulation
- IAP AGCM-I + 20L G-OGCM(1994)
  - CO2 effects
- **CGCM 2: IAP AGCM-I + 14L 1° x2° TP-OGCM(1996)**
  - ENSO simulation and prediction

IAP AGCMs

- IAP AGCM-I:
  - Vertical resolution: 2 Levels
  - Horizontal resolution: 4x5, 2x2.5, 1x1.25
- IAP AGCM-II
  - Vertical resolution: 9 Levels
  - Horizontal resolution: 4x5, 2x2.5, 1x1.25
- IAP AGCM-III
  - Vertical resolution: 21 Levels
  - Horizontal resolution: 2x2.5

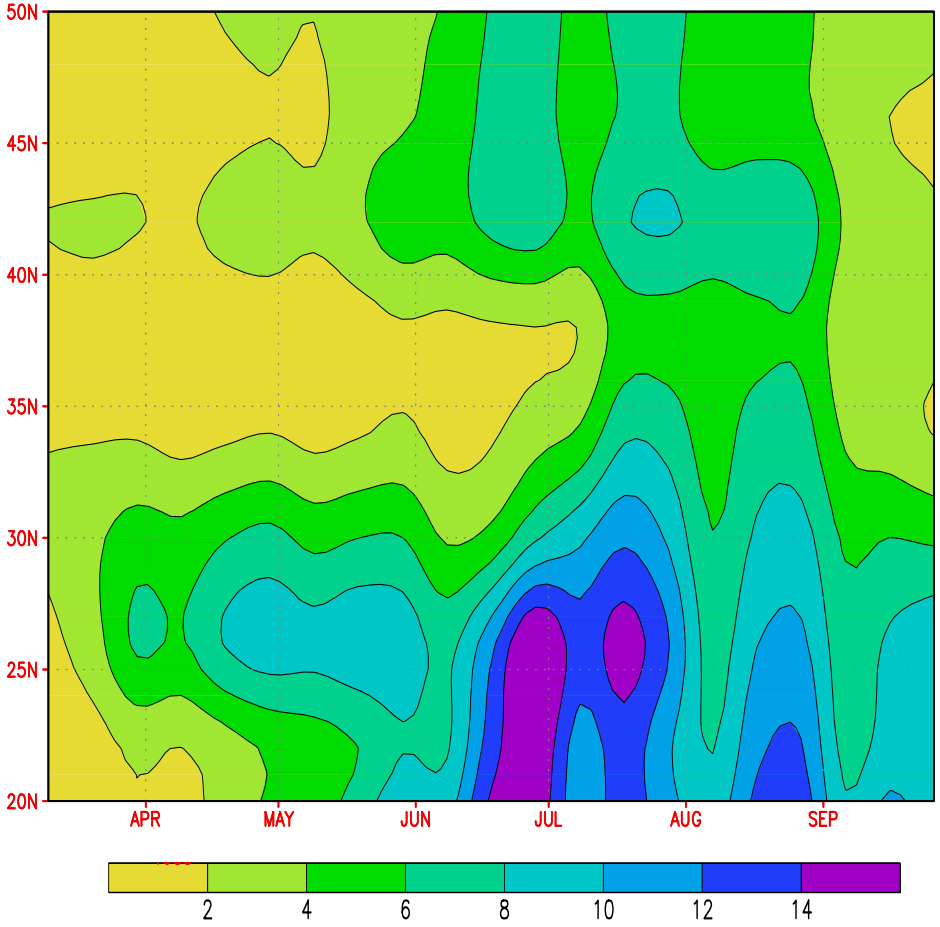
Simulation

Observation

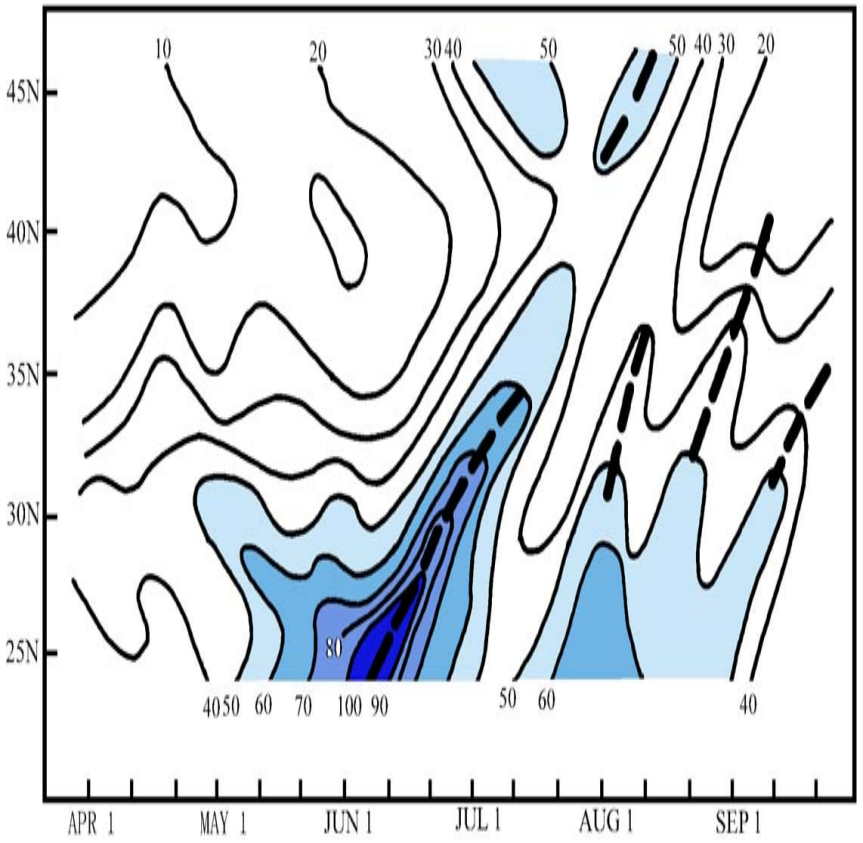


precipitation climatology (mm/day) over East Asian region for June, July and August

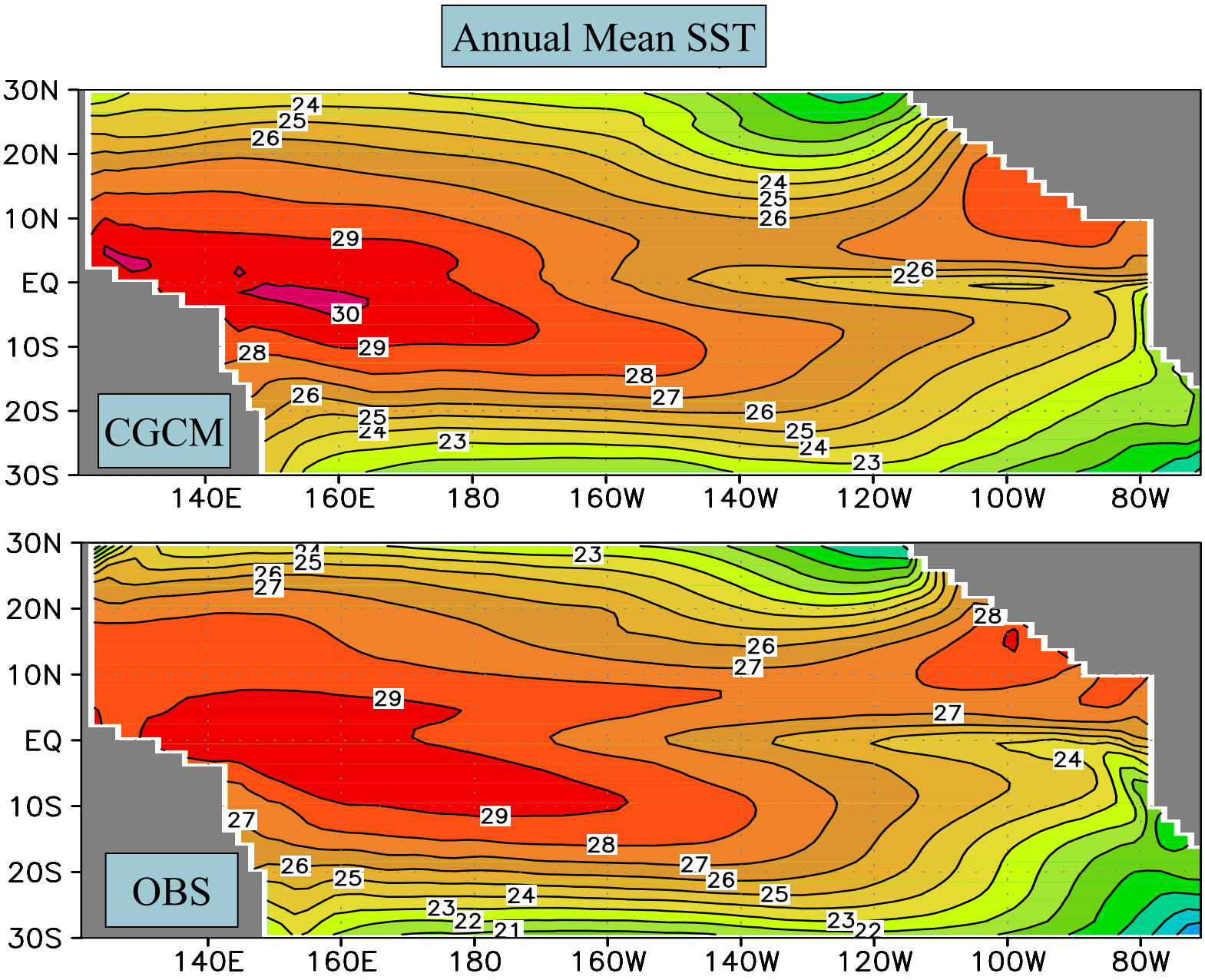
Latitude-time cross section of the 10-day precipitation over Eastern China



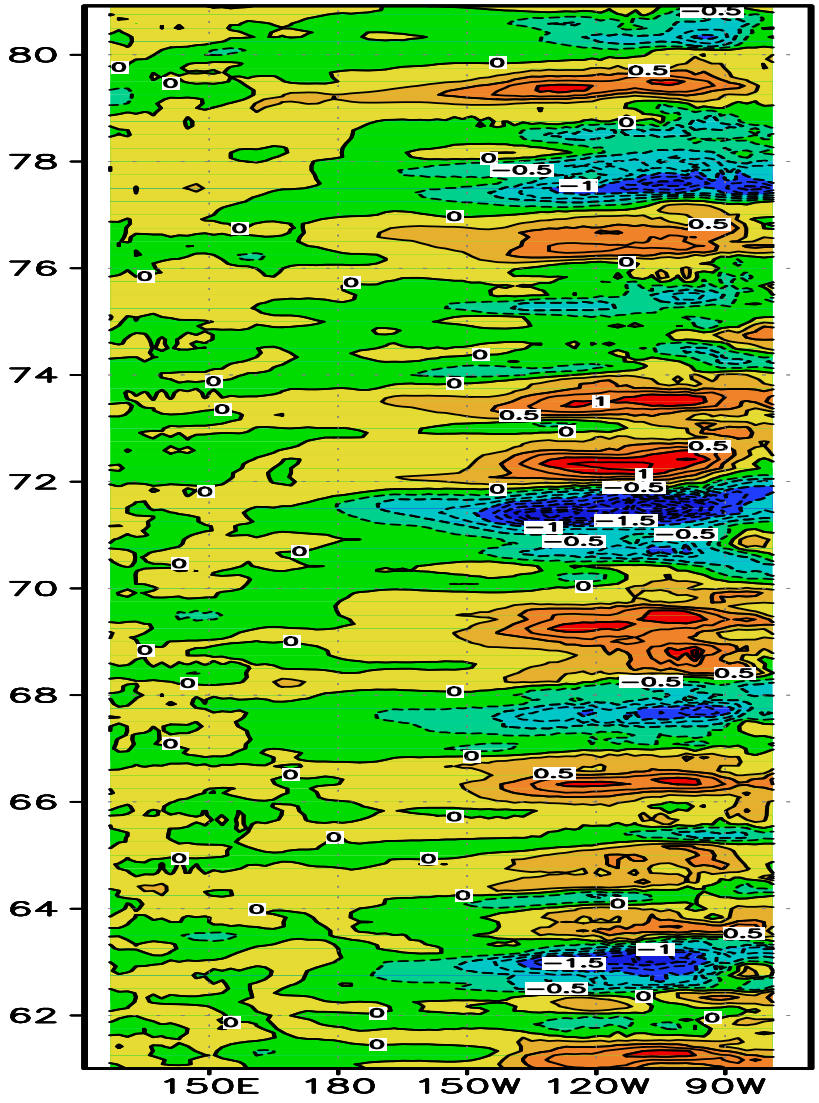
Simulation
(110E-130E)

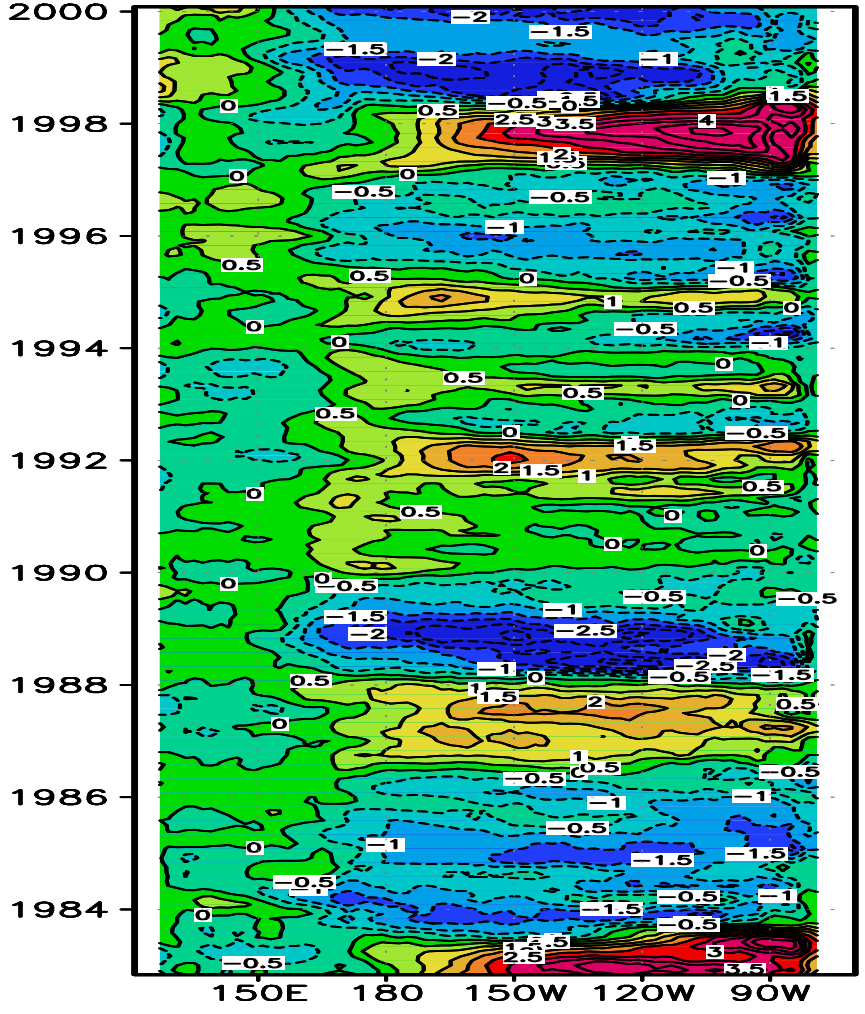


Observation
(Redrawn from Lau et al, 1988)

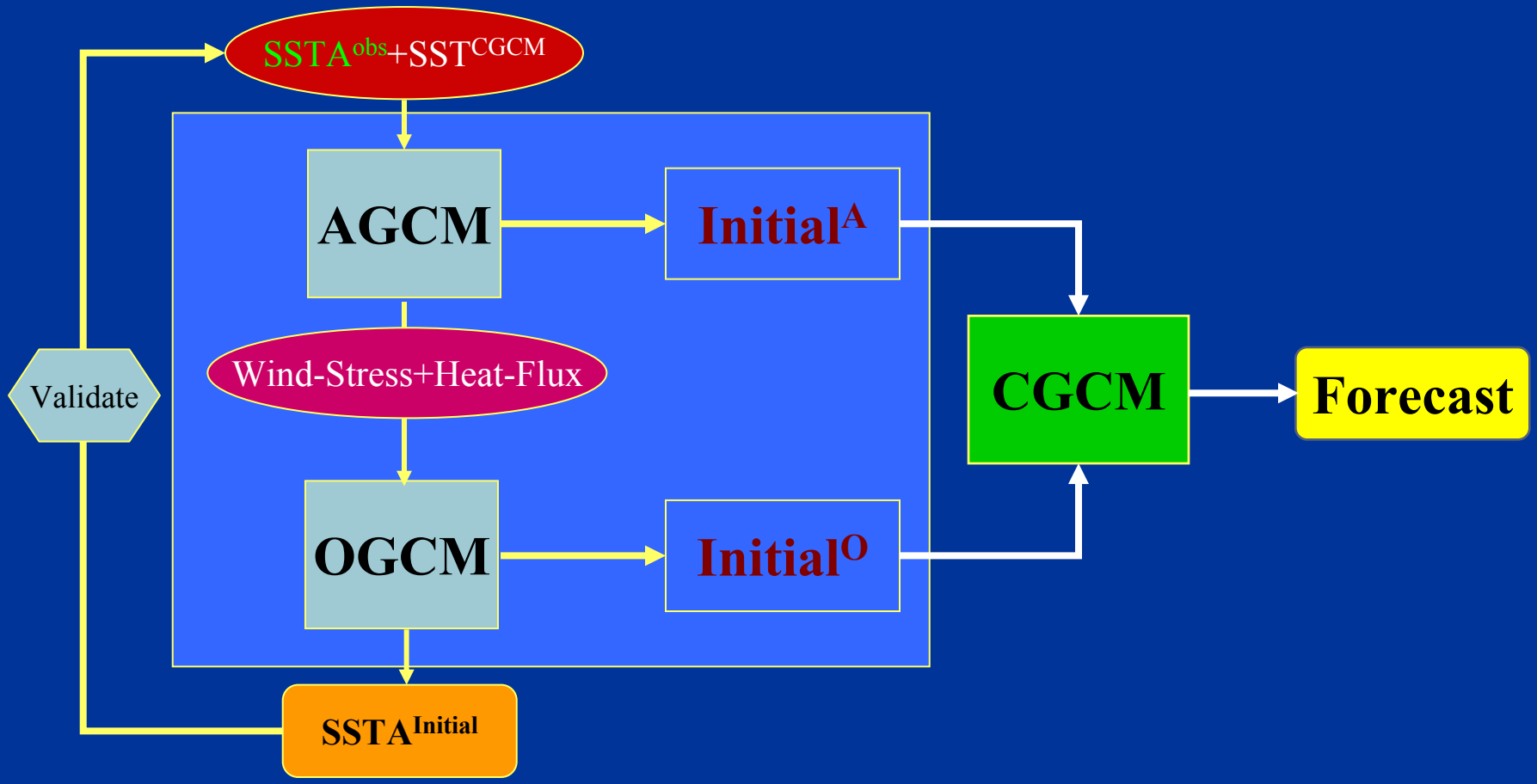

Annual Mean SST
CGCM
OBS
30N
20N
10N
EQ
10S
20S
30S
140E
160E
180
160W
140W
120W
100W
80W

Interannual Variability of the SSTA mainly occurs in Middle and Eastern Pacific, with dominant period of about 4 years

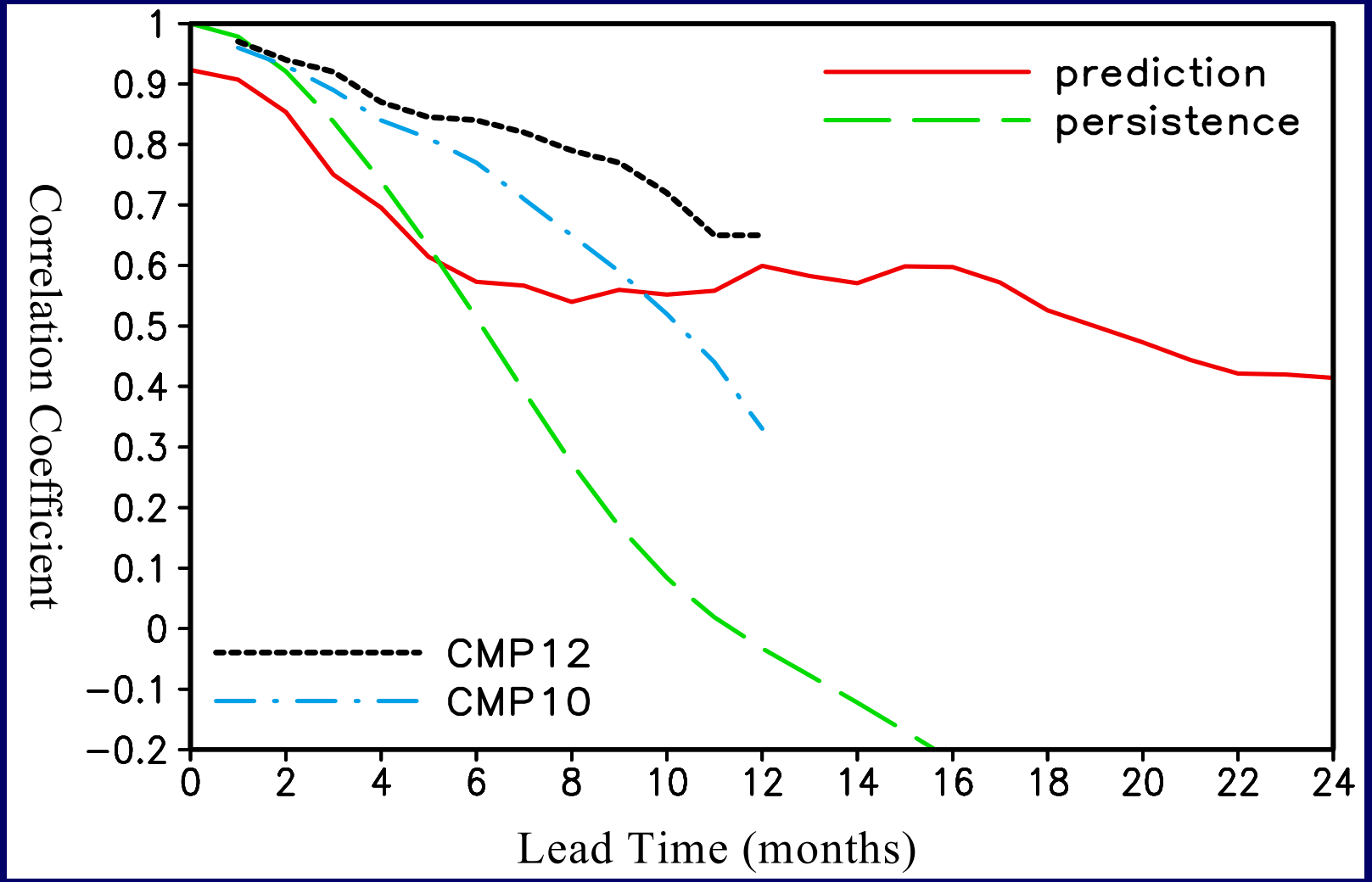




Longitude-Time Cross Section along Equator for the SST anomalies Simulation (Left) and Observation (Right)



Schematic Picture of the Forecast Initialization Process. $SSTA^{obs}$ is observed SST anomaly, SST^{CGCM} is CGCM's Climatology, and $SSTA^{Initail}$ is simualated SST anomaly after 'Initialization Process'.



Skill for the prediction of SSTA over Nino3.4 region (170°W－120°W,5°S－5°N) (correlation between prediction and observation).

Correction System for the seasonal prediction of summer climate anomalies

- 15-year Hindcast Experiments: 1980-1994
- Initial condition: 1-28, February
- SSTA: 1) persisted Feb. SSTA
  2) Observed SSTA from Feb. to Sep.
- Verifications: Observed precipitation data on model grid points based on 336-station data through weighted average

Verification of seasonal prediction

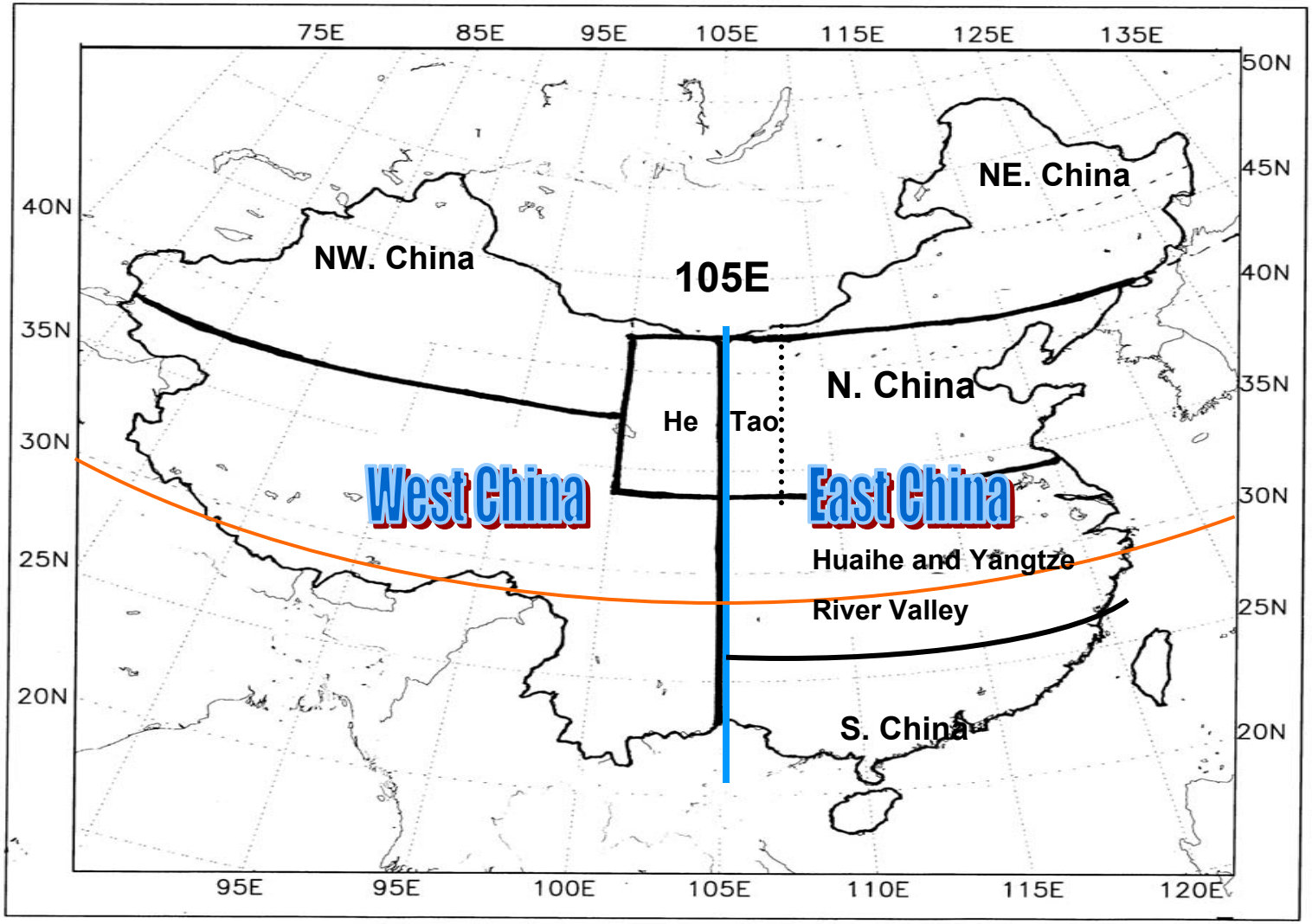
- Anomaly Correlation Coefficient (ACC)

$$ACC = \frac{\sum_{i=1}^{N}(\Delta R_{f,i} - \overline{\Delta R_{f,i}}) \times (\Delta R_{o,i} - \overline{\Delta R_{o,i}})}{\sqrt{\sum_{i=1}^{N}(\Delta R_{f,i} - \overline{\Delta R_{f,i}})^2 \times \sum_{i=1}^{N}(\Delta R_{o,i} - \overline{\Delta R_{o,i}})^2}}$$

N: Total number of stations used for evaluation.

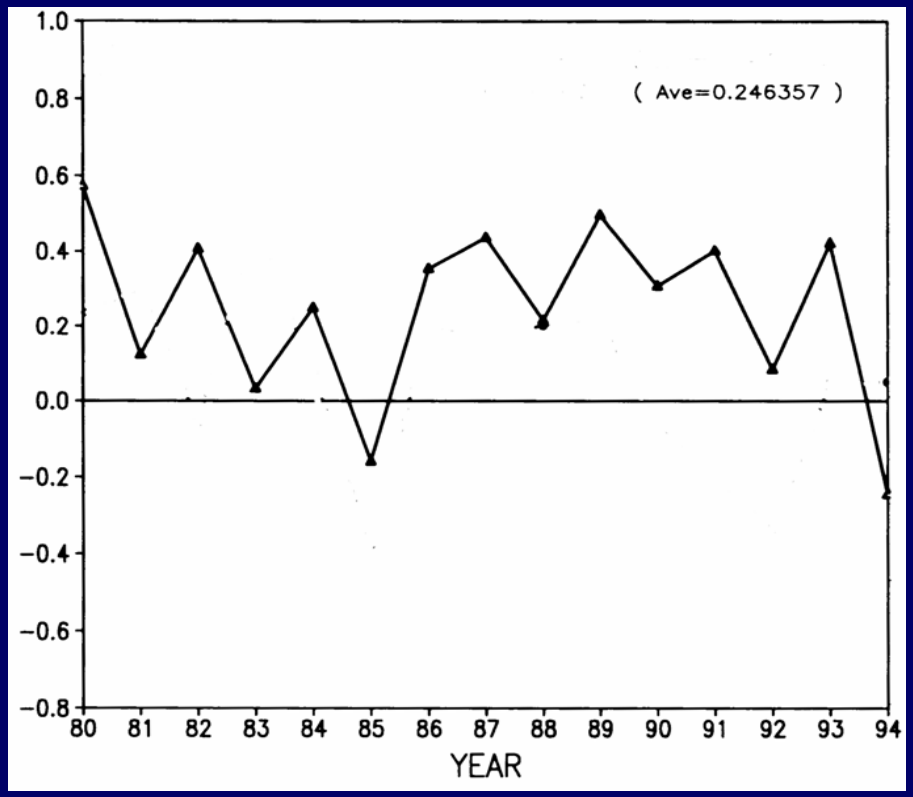
$\triangle R_{f,i}$ and $\overline{\triangle R_{f,i}}$ are predicted anomaly percentage and long-term mean at the ith station, respectively.

$\triangle R_{o,i}$ and $\overline{\triangle R_{o,i}}$ are respective observed anomaly percentage.

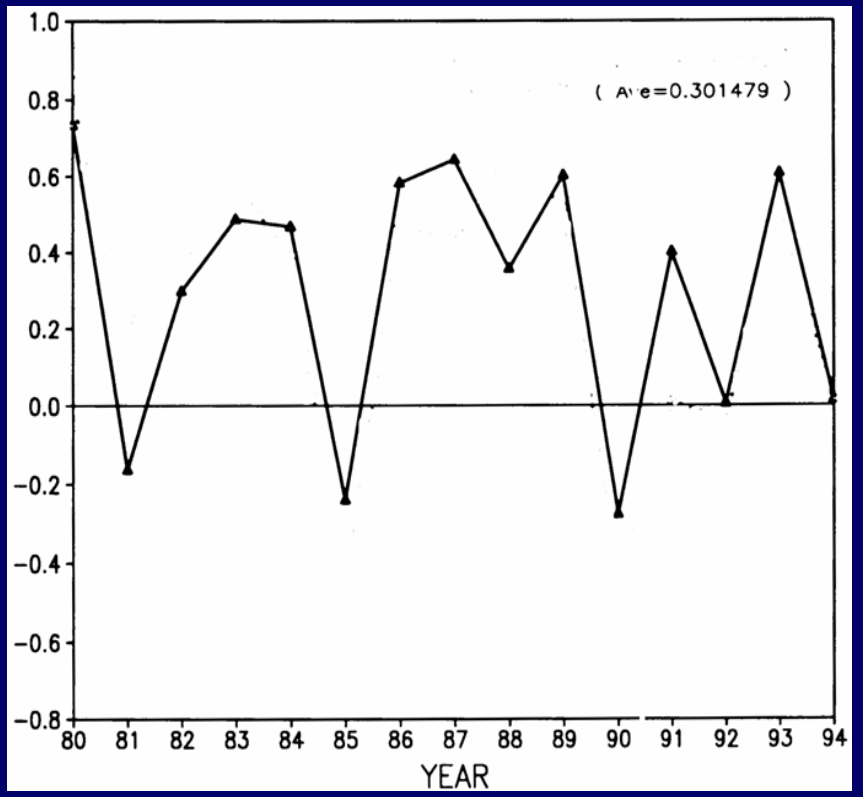


map of China and subregions

Eastern China



Yangtze-Huai River Valley



Anomaly Correlation Coefficient between the observed and predicted summer rainfall anomalies

Seasonal Prediction skill is relative higher over Eastern China, especially over Yangtze river Valley and Southern China

Correction Technology

1. Prediction of Percentage Anomaly of f *(e.g., Rainfall)*

$$a_i = f_{pi} - < f >_{mr}$$

$$b_i = f_{oi} - < f >_{or}$$

a_i, b_i : Predicted and observed **percentage *anomaly*** for *i-th* year respectively

f_{pi}, f_{oi}: Predicted and observed ***state*** for *i-th* year respectively

f_{mr}, f_{or}: Simulated and observed ***reference climatology*** respectively

f_{mr} : 30-year mean of simulated f (rainfall) produced by 30-year AGCM integration forced by observed SST climatology

f_{or} : 30-year mean of observed f (rainfall)

$< \cdot >$: the mean over a specific sample set

Correction Technology

2. Percentage Anomaly correction

$$a_i' = a_i - \varepsilon$$

$$\varepsilon = < a_i - b_i >_h = (< f >_{mh} - < f >_{mr}) - (< f >_{oh} - < f >_{or})$$

$< \cdot >_h$ is calculated for a sample set of hindcats(**1980-1994** here)

There exist some inconsistency among the samples used to calculate the predicted and observed anomalies, therefore, usually, $\varepsilon \neq 0$

----- without interannual Variability

Integration Scheme

Two-step Integration:

Step I: Predict the SSTA by a coupled A-O GCM (IAP TOGA-I) for providing the lower boundary conditions of AGCM

Step II: Integrate the AGCM with different atmospheric initial conditions (for ensemble prediction)

Anomaly Coupling technique

- Over Tropical Pacific Region, SSTA used in IAP DCP is the linear combination of Observed Feb. SSTA and forecasted SSTA by IAP ENSO prediction system：

$$(SSTA)^t=\alpha(t)*[(SSTA)_{to}]+[1-\alpha(t)][K*(SSTA)_{Fcst}]^t$$

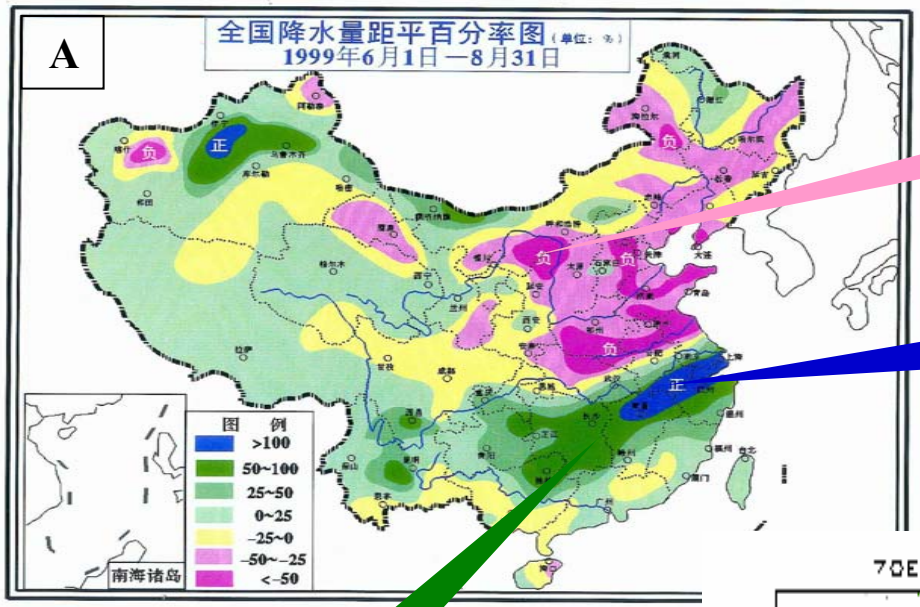
Here, n=1,…12, Corresponding to Jan. ~ Dec.

- Over other regions, SSTA is kept as the observed SSTA in Feb.

Real-time Seasonal Prediction Scheme

Atmospheric Initial Conditions	Interpolate the NCEP Real-time Analysis Data to Model Grid point (U, V, P, RH).
Sea Surface Temperature	Combination of the observed Feb. SSTA and the predicted SSTA by IAP ENSO Prediction System
Land Conditions	Model Climatology
Ensemble Size	28 members (from February 1st~28th)
Duration of Integration	February ~September

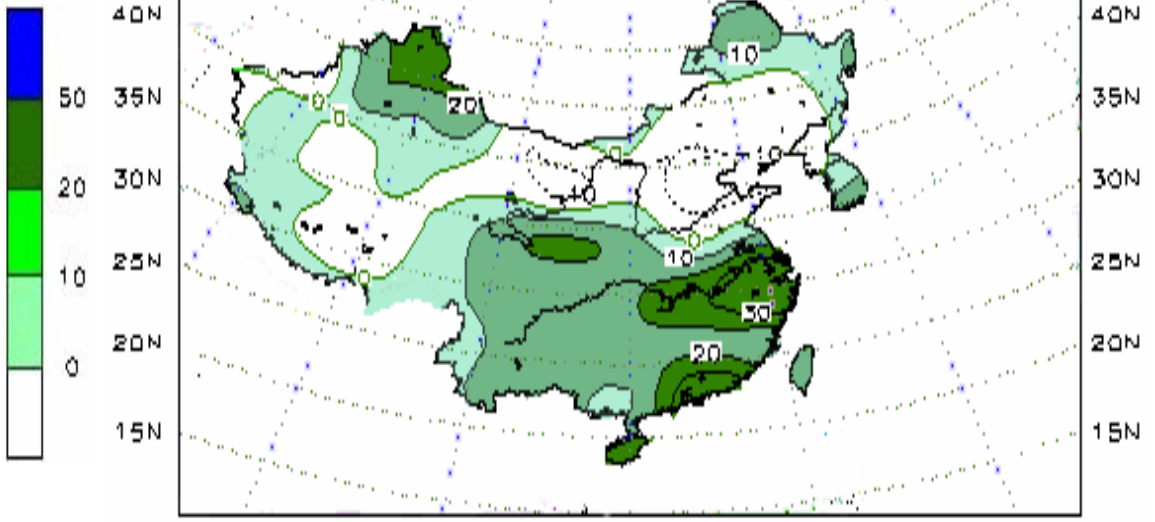
Percentage Summer Rainfall Anomaly for 1999



Drought over North China

Flood over Middle and lower reach of Yangtze river valley

Positive Rainfall anomaly over Southern China

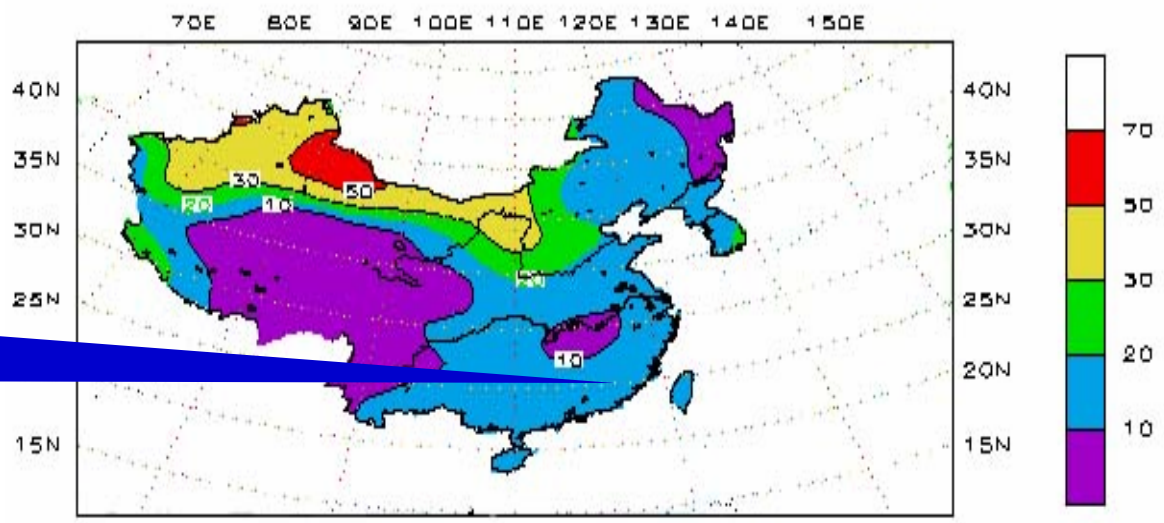


Standard Deviation and Probability Distribution for Ensemble Prediction

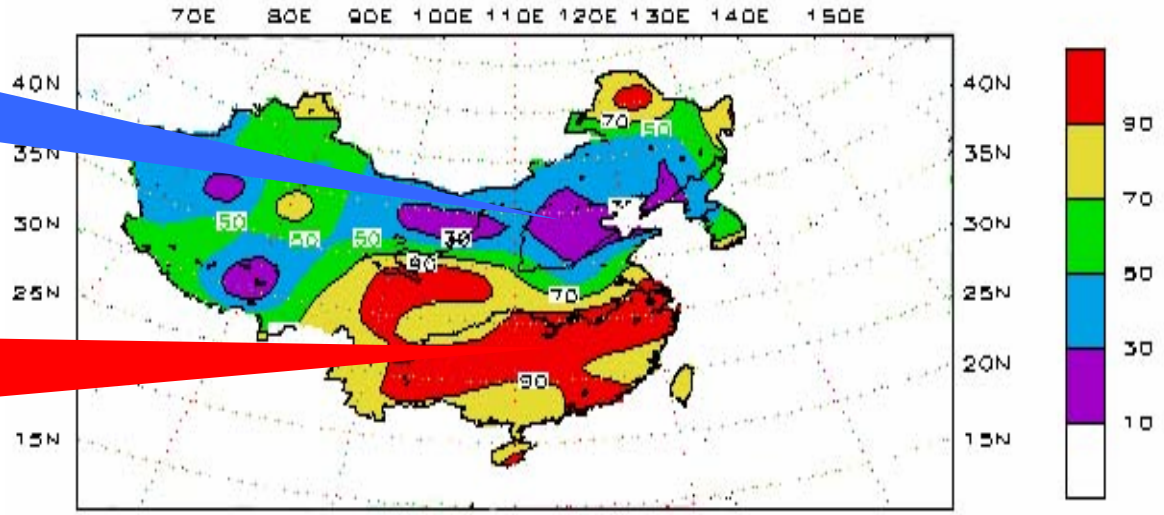
Small in Eastern and Southern China

Large probability for negative rainfall anomaly over North China

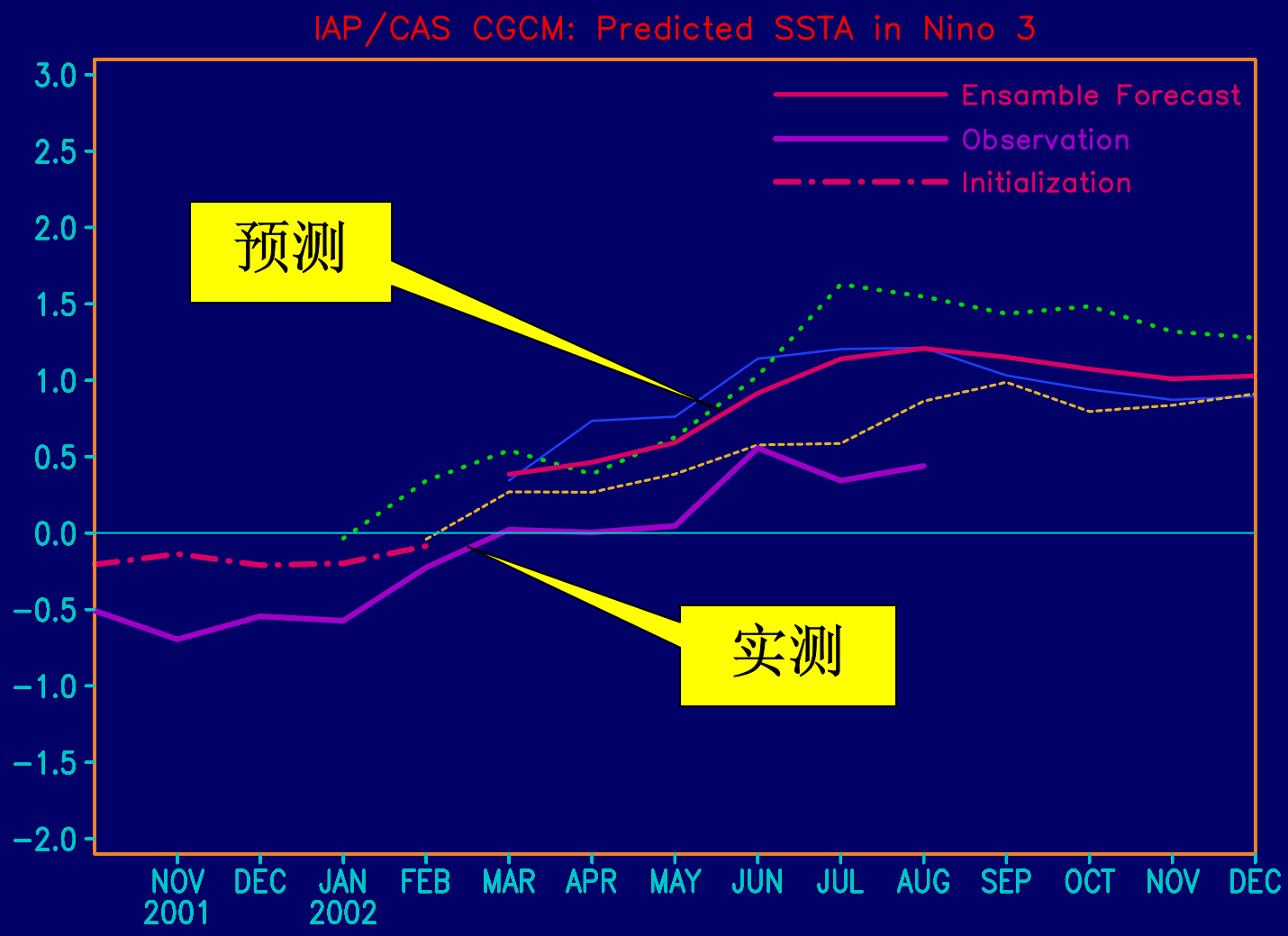
Large probability for positive rainfall anomaly over South China



SD

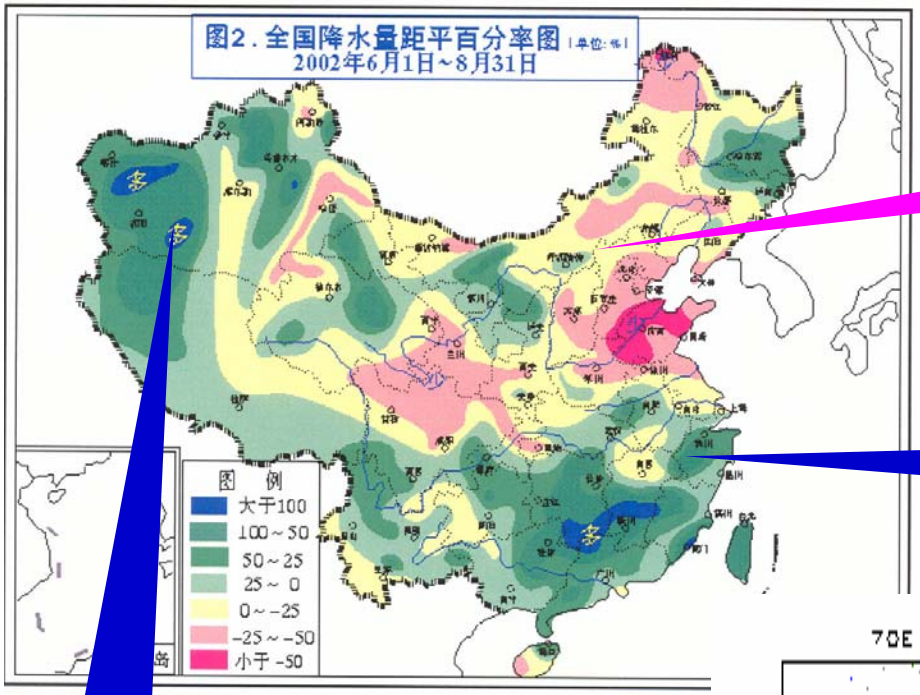


$P^{(+)}$



2002年1、2、3月每月1日为初值的预报及合成预报

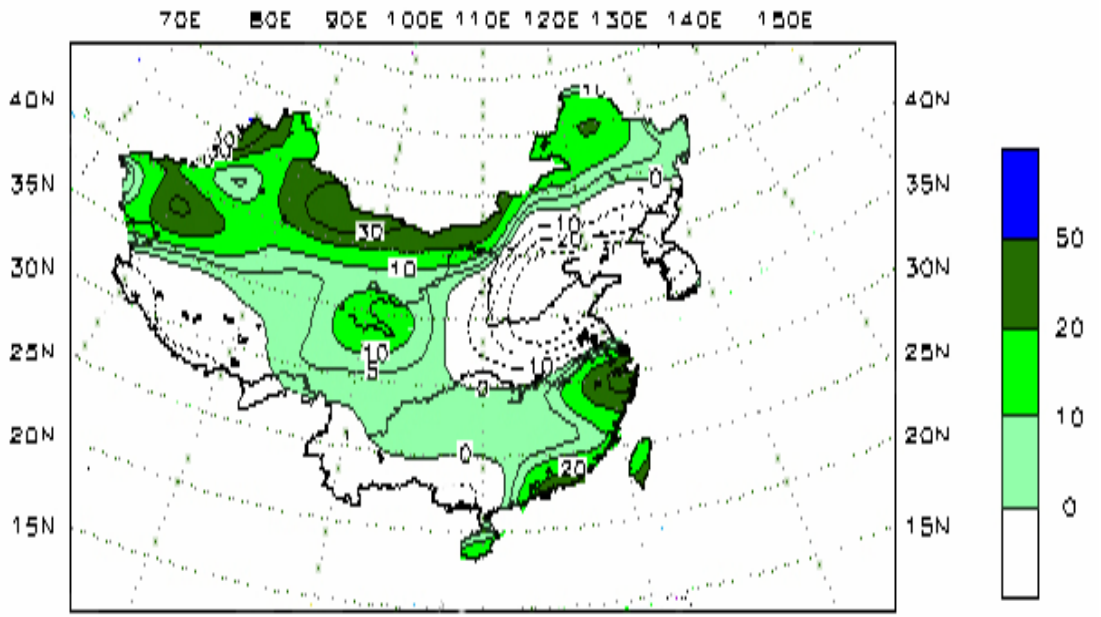
Percentage Summer Rainfall Anomaly for 2002



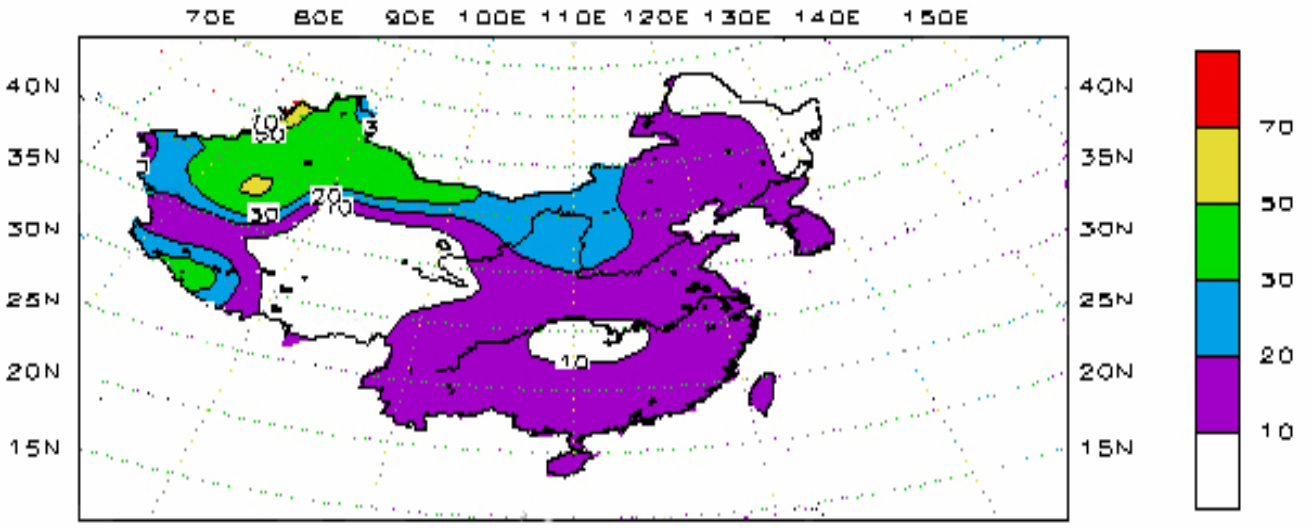
Drought conditions remain over most part of North China

Positive rainfall anomaly over lower reach of Yangtze River

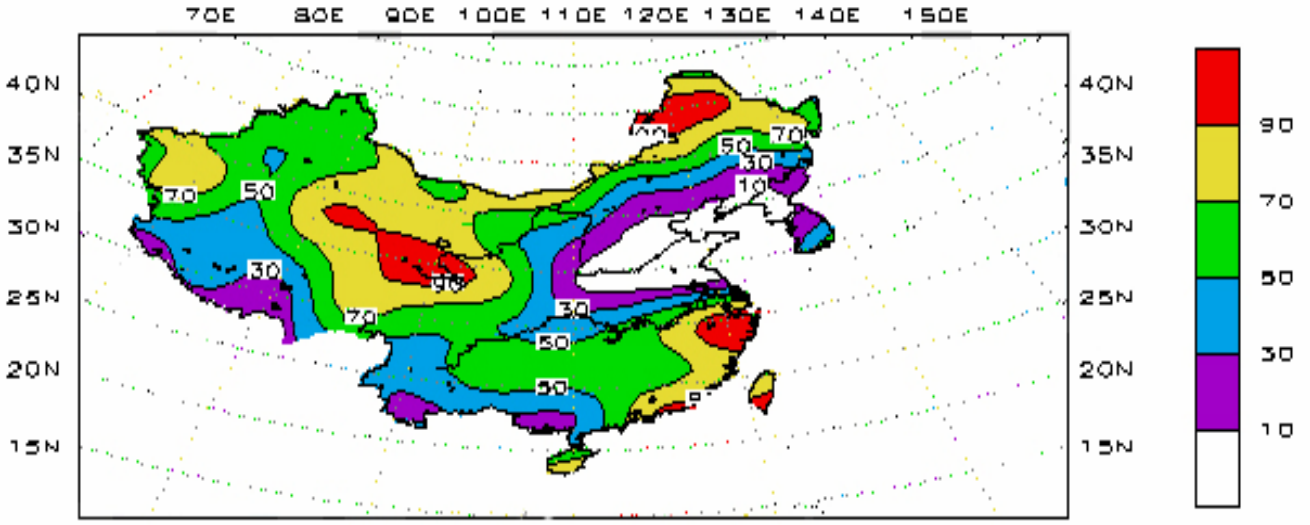
Positive rainfall anomaly over Northwest China



Standard Deviation and Probability Distribution for Ensemble Prediction



SD

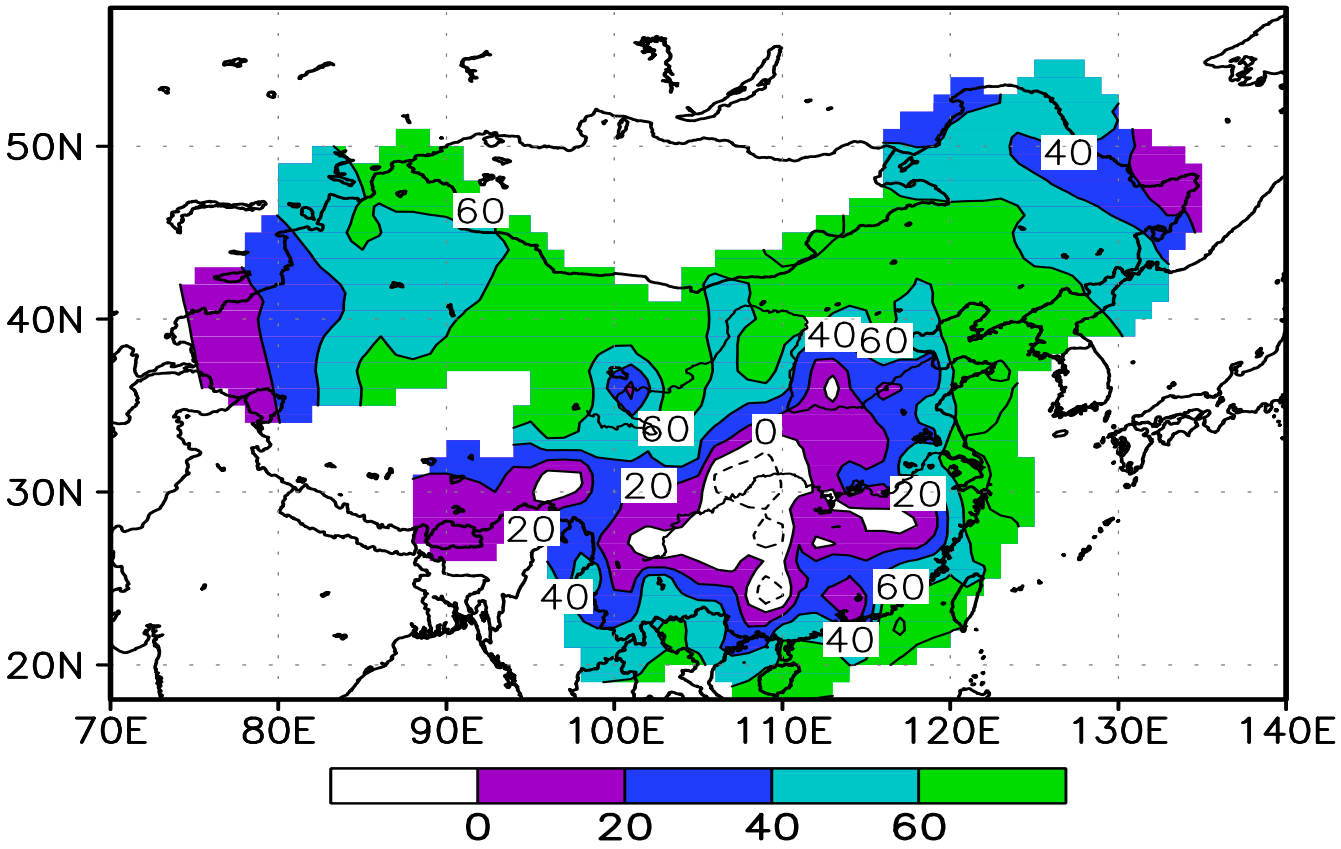


$P^{(+)}$

Hindcast experiment for annual climate anomalies

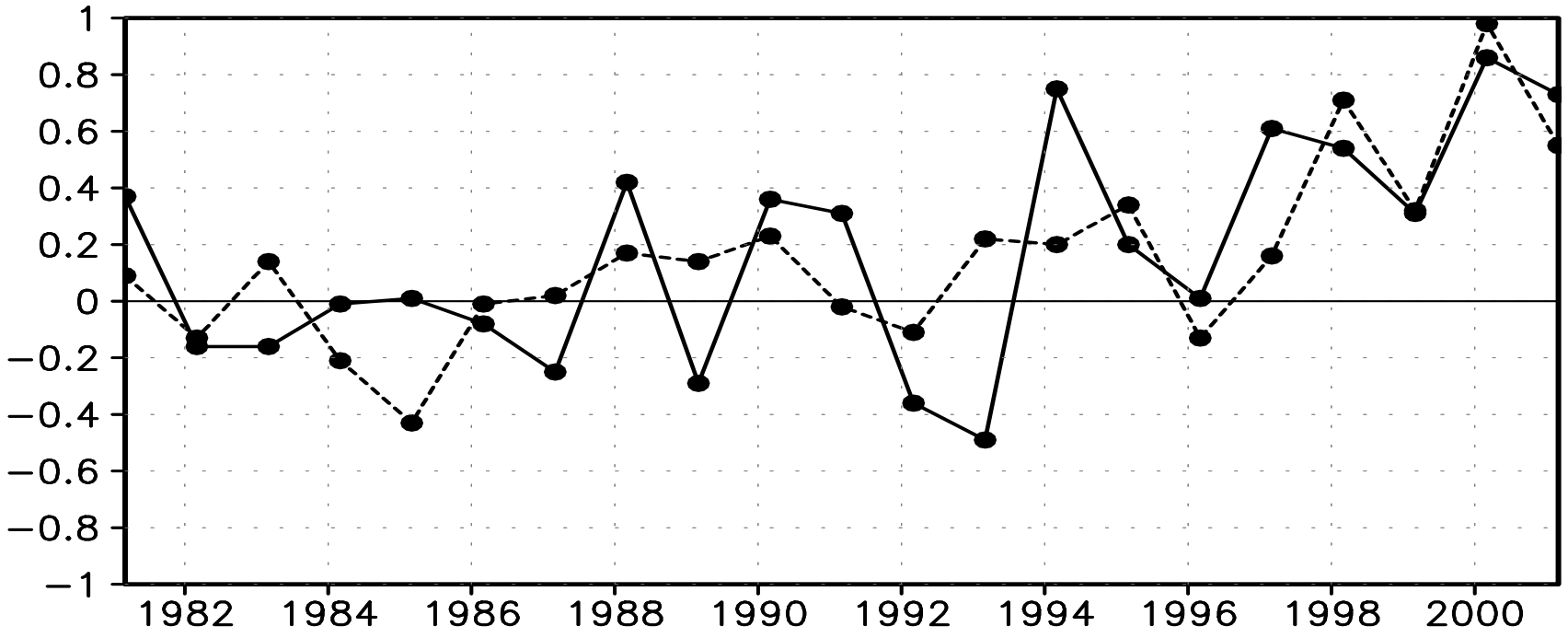
- 21-year Hindcast Experiments: 1980-2000
- Initial condition: 1-31, October for the preceding year
- SSTA: Observed SSTA from Oct. to next Sep.
- Verifications: Observed precipitation data on model grid points based on 336-station data through weighted average

Anomaly correlation coefficient of JJA mean temperature between the observation and interannual prediction (initiated from the October 1-28 for the preceding year)



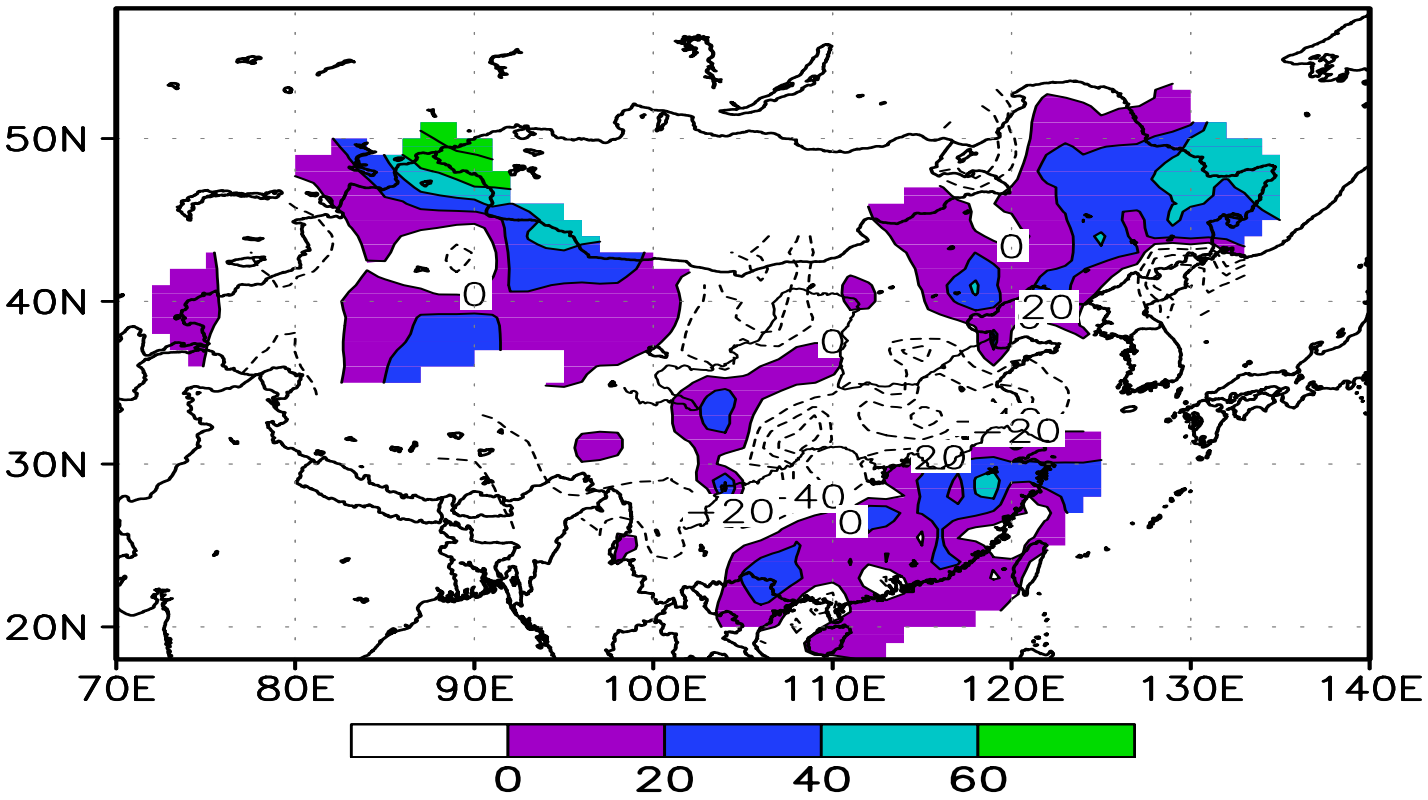
Over most part of China, ACC is relatively high, with magnitude larger than 0.6 . Over the whole 160 stations, there are about 110 stations with ACC larger than 0.2

Interannual variability of the summer temperature anomalies averaged over 160 stations over China（Solid line：Observation；Dashed line：interannual Prediction initiated from preceding October ）



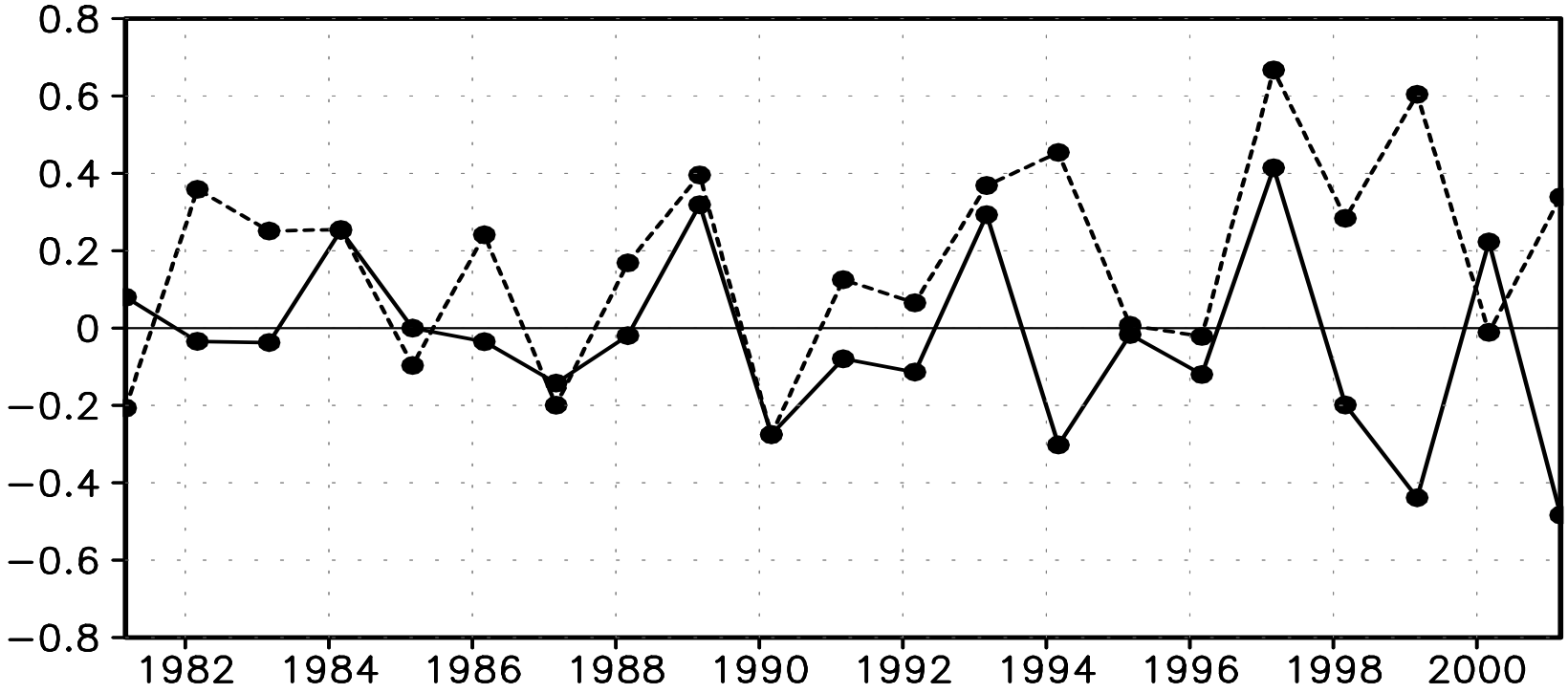
1994开始夏季全国气温偏高，模式较好地模拟出了这一变化，对温度的逐年变化趋势模拟的也比较成功。

Anomaly correlation coefficient of JJA mean Precipitation between the observation and interannual prediction (initiated from the preceding October 1-28)



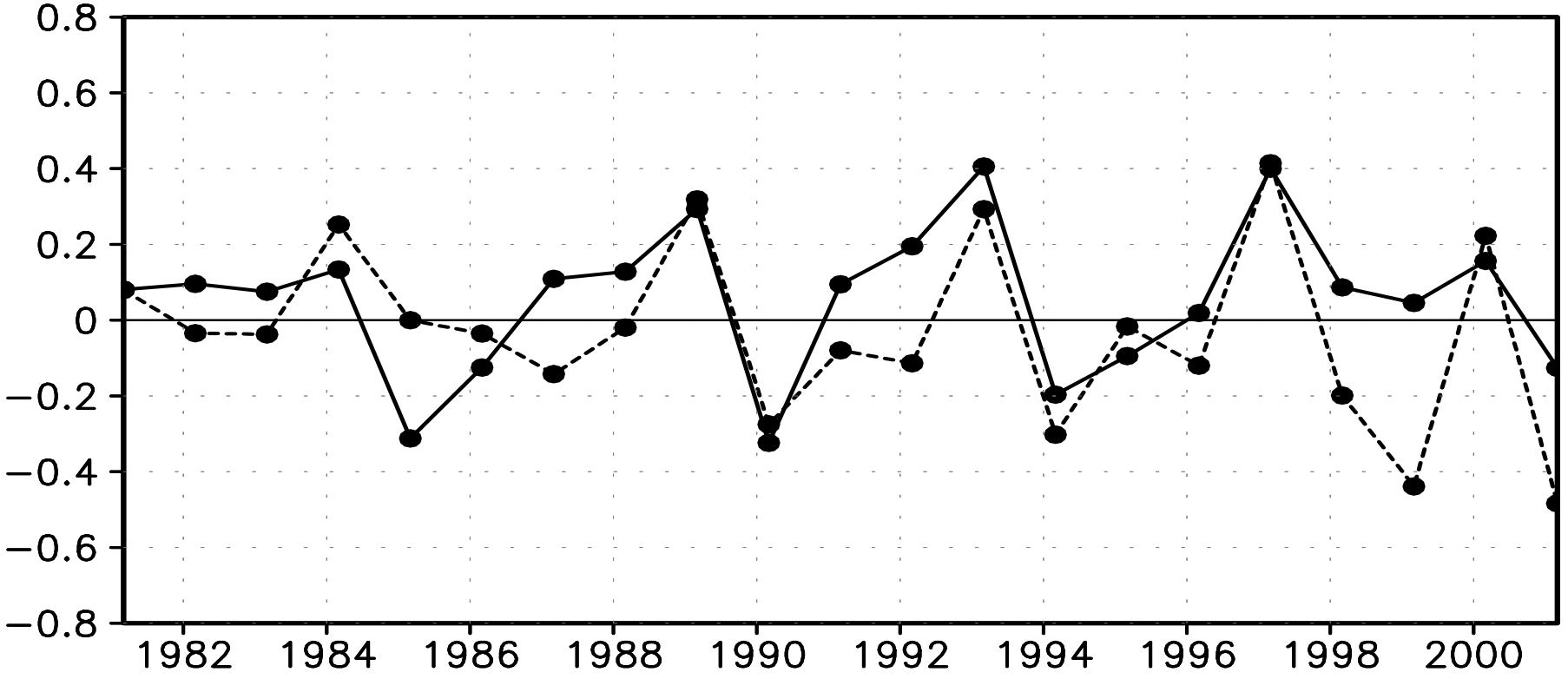
Relative higher predictive skill over Northwest、 Northeast China and South China

Time series of the ACC between the observation and interannual prediction initiated from preceding October. (Dashed line: temperature; Solid line: Precipitation. All the results are uncorrected)

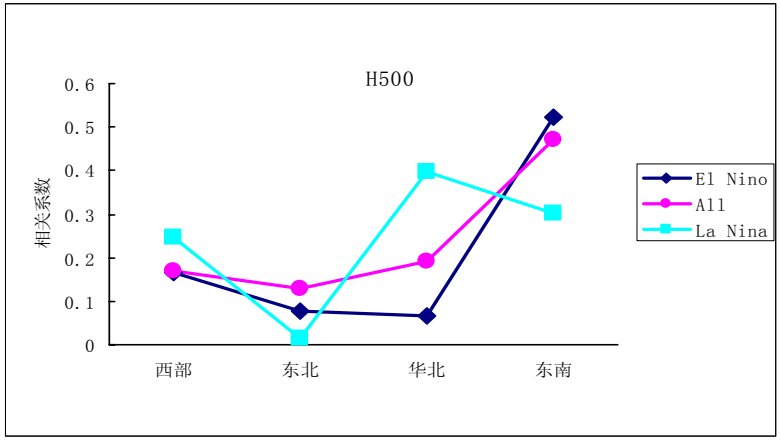


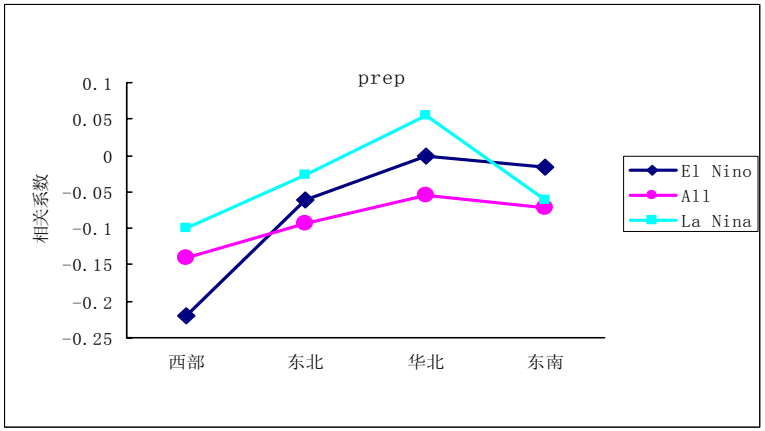
温度场除1981、1985、1987、1990、1996年外，其它年份相关系数均为正，且有一半以上年份的相关系数超过了0.01的显著性检验（相关系数大于0.24）。相对而言，降水的预报技巧较低

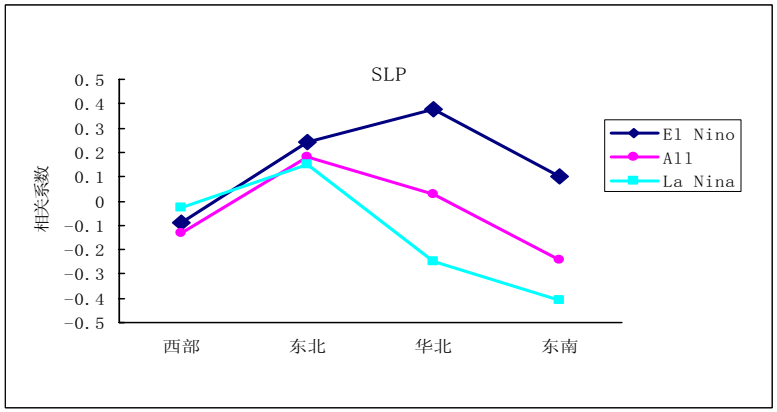
Time series of the ACC of precipitation between the observation and interannual prediction initiated from preceding October. (Dashed line: uncorrected; Solid line: corrected.)

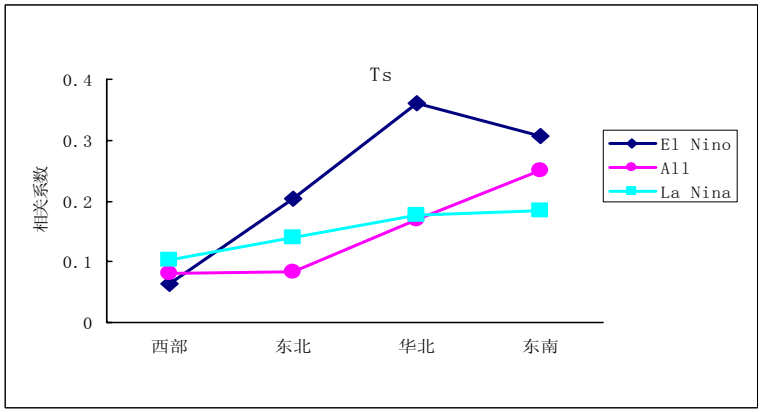


Dependence predictive skill with ENSO cycle over different regions of China



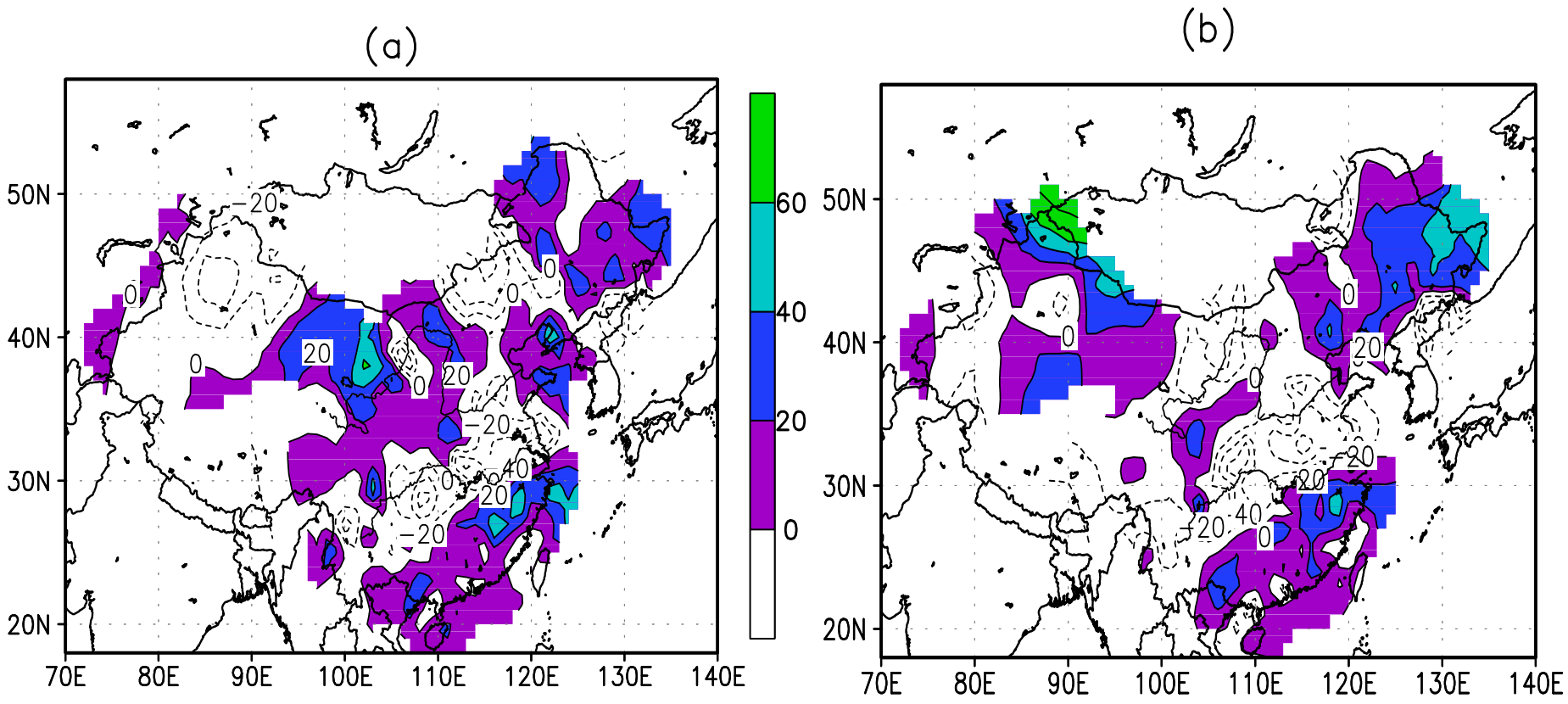






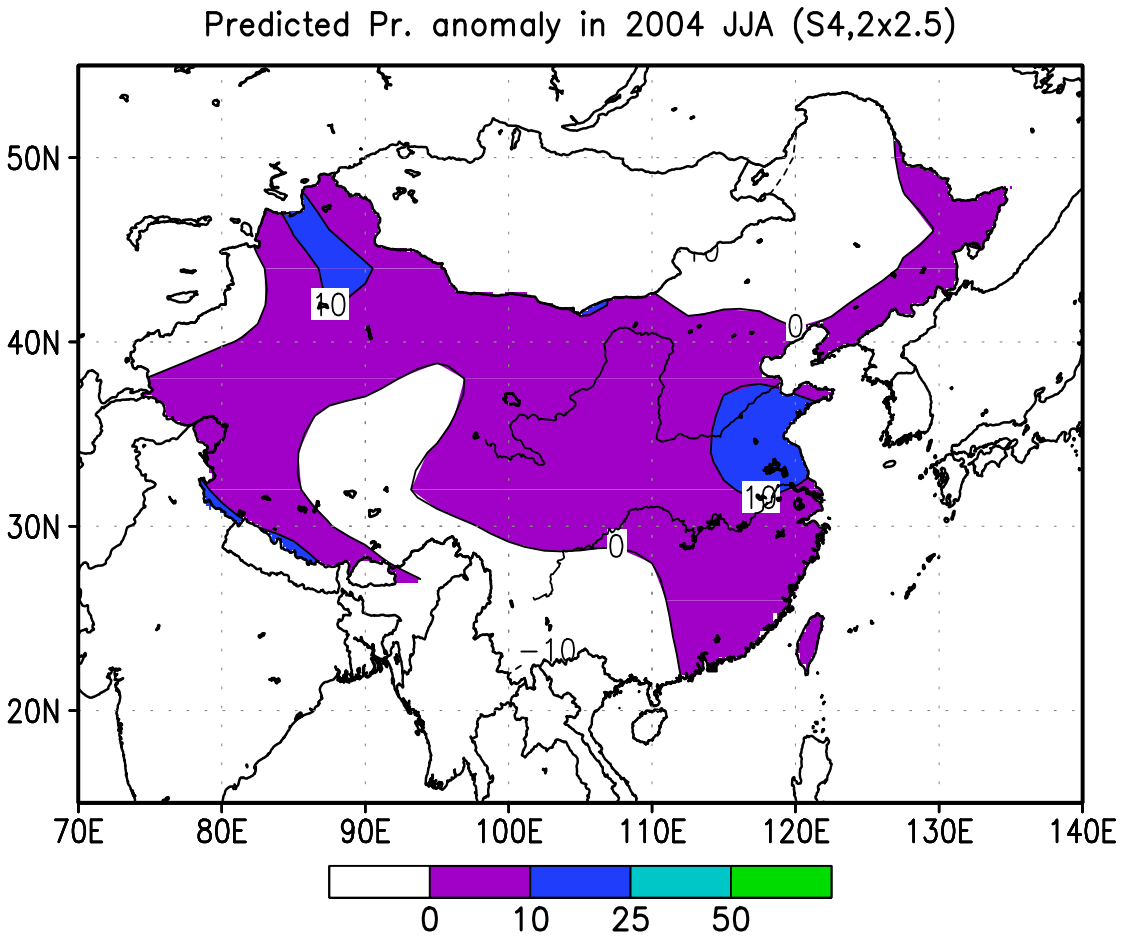
Over Southeast China, the annual predictive skill is relative high for El Nino years compared with La Nina years

Comparison of the predictive skill of summer rainfall anomalies for the （a）Extra-seasonal prediction（b）Interannual prediction



Generally, the extra-seasonal predictive skill is relatively higher compared with the interannual prediction; with the significant difference located over mid-latitude region.

Outlook of the summer rainfall anomalies for year 2004 by IAP DCP (Initiated from Sep. 2003)



Summary

- IAP ENSO Prediction system is Generally skillful in the prediction of major El Nino and La Nina events.
- IAP Dynamical Climate Prediction system (IAP DCP) shows certain capability in the prediction of summer rainfall anomalies over China during recent years, especially for the persistent drought conditions in North China and severe flood conditions over Yangtze river and Southern part of China.

Summary

- There also exists certain predictability for the annual prediction of summer climate anomalies, and the predictive skill is relatively higher for temperature compared with rainfall.
- Compared with the annual prediction, the predictive skill for extra-seasonal prediction is relatively higher over most part of China; However, over the Northwest China, the skill for annual climate prediction is relatively higher.

Future Issues

- Spatial and temporal restrictions
  - Higher resolution model
  - Regional model
- Model initialization
  - Oceanic data assimilation system
  - Land data assimilation system
- Ensemble runs
  - Multi-model ensemble technique
- Correction System
- Extending the geographical range of SST predictions

Thank You